THE

PHYSIOLOGY OF HEALTH:

BEING A

View of some of the more important Functions

OF THE

HUMAN BODY;

WITH A

FEW PRACTICAL OBSERVATIONS

ON

THEIR MANAGEMENT.

LONDON:

T. M. CRADOCK, 48, PATERNOSTER-ROW.

1841.

CONTENTS.

PHYSIOLOGY OF HEALTH.

ANIMAL bodies are made up of a series of textures or *tissues*, which are combined together to form various parts or *organs*, each of which is adapted for the performance of some particular action or *function*. As examples of tissues may be mentioned *Cellular tissue*, which binds together and connects most of the organs of the body; *Muscular* or *Contractile fibre*, popularly known as flesh, possessed of the power of shortening itself, and so moving parts to which it is attached; *Membrane*, generally investing or lining internal parts, and *Nerve*, endowed with the faculty of receiving and transmitting sensations. We have an example of an organ in the Heart, composed as it is essentially of muscular fibres, bound together by cellular tissue, invested and lined with membrane, and furnished with nerves; and function is illustrated by the duty or action performed by the heart, of transmitting the blood through all the different parts of the body.

The science which treats of the nature and properties of tissues is called *General Anatomy;* that which makes us acquainted with the formation and position of organs is *Special* or *Descriptive Anatomy*, and that which investigates the functions is *Physiology*.

When an organ or its function has become altered or impaired, we are made aware of the fact by the occurrence of a series of phenomena, which the knowledge of Physi-

ology teaches us to be at variance with the natural or healthy state. The science which judges of the nature of these symptoms, and traces them to their cause and origin, is the doctrine of disease, or *Pathology*, and the study of the means of removing diseases is embraced under the allied sciences of *Practical Medicine* and *Surgery*.

There are three ways in which the removal of disease may be accomplished.

I. There is the performance of certain manual operations on the body. This is one branch of Surgery.

II. There is the employment of certain external agents, *medicines*, which experience has shewn to have the power of affecting the organs or functions of the living body, and of producing in them phenomena, by which the morbid processes going on in the system are counteracted or arrested.

III. There is the regulation of the functions themselves, or of the external agents usually concerned in their performance, constituting the important subject of *Hygiène* (from HYGEIA, the goddess of Health) or *Regimen*. The last of these means is by far the most important, not only because, in the treatment of existing diseases, it opens to us in many instances the most effectual and least disagreeable way of removing them, but because, if properly attended to, it furnishes us with the means of preventing their occurrence. It may almost be said that there are few diseases which may not be traced originally to violations of some of the rules of Hygiène.

It will readily be perceived that the sciences of Physiology and Hygiène are inseparably connected, and in fact Hygiène may almost be said to be practical Physiology; for it consists essentially in the management of the external agents which operate upon the functions of the body, so as to preserve these functions in their natural or physiological condition.

We propose in the following pages to make our readers acquainted with the nature of some of the more important

functions of the human body, and to add a few practical observations as to their regulation. We cannot pretend, in the short space which our limits afford, to go over all, or even the greater part of what is now known of Physiology. We shall avoid topics of a purely speculative nature, and we limit our remarks to a few of the more important functions of the body, leaving out of view altogether the physiology of the mind, which forms in itself a large and noble field of interesting inquiry.

The functions have been variously classified by different authors, according to their views of general physiological laws. We consider it unnecessary here to enter into any discussion as to the best classification, and we simply adopt, as most convenient, the arrangement given by M. Magendie, into

I. *The functions of relation*, or those which connect the animal with surrounding objects; such, for example, as the senses of sight, hearing, and smell, the power of speech, the property of locomotion, and the mental faculties.

II. *The nutritive functions*, or those which tend to maintain the body of an existing animal in full health and vigour.

III. *The reproductive functions*, or those which enable animals to propagate their species.

The two last of these classes of functions are, in great measure, enjoyed by plants as well as animals; those of the first class are peculiar to animals.

We think it best, in accordance with the practical purpose which we have in view in writing these pages, to confine ourselves to the consideration of those of the second class; for although every one of the functions may be the subject of practical rules for its improvement or maintenance, and though the physiology of the senses and of reproduction are amongst the most interesting questions which can be discussed, we think it better, as our space is limited, to devote it to the consideration of those functions

which will furnish us not only with subjects of interest, but with matters of direct practical utility.

By the *nutritive functions* we would have our readers to understand, not merely the conveyance of nourishment to our bodies, but also the various processes by which what is so conveyed is rendered exactly fit for the maintenance of life; and also the means by which whatever is either noxious to, or unnecessary for the body may be got rid of. The chief of these processes are, *Digestion*, or that by which food is taken, and so prepared as to form blood, the great nourishing fluid of the body; *Circulation*, by which the blood so formed is carried to all parts of the system; *Respiration*, by which the blood is kept in a condition fitted for the maintenance of life; and *Absorption* and *Secretion*, by which certain substances are removed from the body, which are either unessential or injurious to its healthy condition.

Of Digestion.

The bodies of animals undergo a continual series of changes from the time of birth to that of death, in point of form, dimension, and structure, which occasion a constant loss of the constituent particles of the body, and which, therefore, entail upon us the necessity for an equally constant supply of nourishment, to counterbalance the losses thus occasioned. We obviously require food to add to the body during the period of its growth; but even when we have acquired the full grown or adult condition, we lose daily in the form of various excretions, such as perspiration, urine, &c. a considerable weight of matters, which if not compensated for, leave the body emaciated and enfeebled. The substances which we use to counterbalance these losses are called *Aliments;* the process which prepares them for being incorporated with our bodies is *Digestion;* and the organs which carry on this process, are the Stomach

and Intestines, forming the *Alimentary canal,* with certain other parts connected with them, which may be all comprehended under the general title of the *Digestive organs.*

Of the Digestive Organs.—This term embraces the mouth and gullet, with the teeth and salivary glands, the stomach and intestines, with the spleen, liver, and pancreas.

The mouth, or aperture by which food is introduced into the body, in man and quadrupeds contains the teeth, which are a series of cutting organs fixed in the jaws, by means of which the food is masticated or chewed, that is, it is more or less divided, so that it is not only more easily formed into such a shape as to facilitate its being swallowed, but is afterwards more easily acted on by the digestive powers of the stomach. At the same time that the food is being chewed, it is mixed with the saliva, a fluid which is secreted or formed by a series of bodies called the *Salivary Glands.* These are three in number on each side. First, the *Parotid gland,* situated before the ear, and behind the angle of the lower jaw. It communicates with the mouth by a small duct or canal, which, passing through the muscle of the cheek, opens into the mouth by a small opening opposite the second grinder of the upper jaw; secondly, the *submaxillary gland,* situated below the lower jaw between its angle and the chin, its duct opens beside the band or *frœnum* of the tongue; and thirdly, the *sublingual gland,* lying in the mouth below the tongue, beside the frœnum of which it discharges its secretion into the mouth by several small openings. The saliva secreted by these different glands is identical in quality, and its use seems to be to moisten the morsel of food, to render it more easily swallowed, and perhaps also to aid its digestion, by acting on some of its more soluble constituents. The next part of the alimentary canal is the *pharynx,* or top of the gullet, and the *œsophagus* or gullet itself; this is a muscular canal, the upper part of which contracts in obedience to the will, but the lower part of which contracts independently of the will on any substance

contained in it, and pushes it downwards towards the next and most important part of the alimentary canal.

The Stomach.—This organ varies in form in different animals. In the human subject, it consists of a large membranous bag lying across the upper part of the belly, close below the midriff or *diaphragm*, which is a large flat muscle stretched horizontally across the body, and which separates the chest or *thorax* from the belly or *abdomen*. The stomach has somewhat of a pear shape, but it is bent slightly on itself, so that when lying flat and empty it assumes a semi-lunar form. Its larger or round end, called the *Cardia*, lies to the left side below the anterior extremities of the lower ribs. It is at the upper part of this round end that the gullet enters. The stomach runs obliquely across the body to the right side, tapering toward its right extremity, and terminates in a round opening called the *pylorus*, which opens into the uppermost part of the intestines. The stomach varies in capacity in different individuals; according to the German anatomist Soemerring, it is capable, when moderately distended, of containing from five to eleven pints of water. We have called the stomach a membranous bag, for so it is in man, but it is not composed of a simple membrane. It is made up of several layers, and in its general structure in this respect, it is identical with the intestines, so that what is said of the one applies also to the other. The stomach and intestines then, consist essentially of an inner coat called the *mucous membrane*, which has a soft velvety feel, and lies in a great many wrinkles or folds. It contains in its substance a variety of glands, differing in form in the different parts of the alimentary canal, which pour forth a slimy or mucous secretion. Outside the mucous membrane lies the *muscular coat*, consisting of a series of muscular or contractile fibres, varying in their form and direction in different parts of the canal, some being circular running round the gut, others being longitudinal and running along it lengthways. They are all characterized,

like every other muscular fibre, by possessing the property of contracting, so as to diminish the cavity of the hollow organs, and so to move and compress whatever is contained within them. Besides these coats, which constitute the essential parts of the structure of the stomach and intestines, there is a fine smooth membrane investing them on the outside, called the *Peritoneum.* It belongs to the class of what are called by anatomists *serous membranes,* i. e. it pours out a fine moisture which covers its smooth surface, by means of which the stomach and intestines are enabled to move freely about when they contract, or when they are expanded by the matters which they contain. The stomach and bowels during life are in a constant state of motion. The movements consist, first, of successive contractions of the circular fibres, by which they mingle and propel onwards the matters which they contain; and secondly, of a rolling motion of the folds of the bowels over each other. These movements are called the *peristaltic* or *vermicular* motions of the bowels.

We return to the consideration of the structure of the alimentary canal, which we had traced as far as the pylorus. Here the intestine commences, and for about the length of twelve finger's breadths it is called the *Duodenum.* This portion of the intestine, on first leaving the stomach, runs toward the right side of the body, rather upwards and backwards towards the liver. It then turns at an angle nearly perpendicularly downwards, and again bending at an angle towards the left, it runs across the spine, where it becomes continuous with the rest of the bowel. It will thus be seen that by its angles it forms somewhat of a triangular figure. At the lower of these two angles, where the perpendicular and horizontal portions meet, there is a small orifice observed in the mucous membrane, which is the opening of the ducts from the liver and pancreas, two organs which we shall mention when we have completed the description of the alimentary canal. The duodenum is continuous with the *small intestine,* of which

it is in fact a part, the divisions being merely arbitrary. The upper two-fifths of the small intestine have received the appellation of the *Jejunum*, and the remaining three-fifths are called the *Ileum*. The small intestine forms the longest part of the alimentary canal, and lies coiled up in convolutions or folds within the abdomen. It terminates below in the deep part of the belly in the right groin, and there communicates with the large intestines. The *large intestine* is distinguished at first sight from the small intestine by its much greater size, and by its being in its whole length puckered into pouches, instead of being a continuous smooth tube. The small intestine opens into a part which is called the *Cœcum*, or blind gut. This, which is the head of the large intestine, projects beyond the orifice of the small intestine, which opens as it were into the side of the large gut, the orifice being furnished with a valve, which in great measure prevents any thing from passing backwards from the large into the small intestine. The large bowel, now called the *Colon*, ascends upwards perpendicularly along the right side, till it comes nearly on a level with the stomach. It then bends at a right angle, runs quite across the body, and again bending at a right angle, passes perpendicularly down along the left side. It thus forms a large arch, within which the convolutions of the smaller intestine appear to lie ; and its three portions are distinguished by the names of the ascending, the transverse, and the descending colon. The large intestine below is continuous with the lower gut, or *Rectum*, which opens out of the body below by the vent, or *Anus*. The whole of the alimentary canal is abundantly supplied with blood vessels and nerves ; and in addition to these, we find running from the small intestines a series of delicate vessels called *Lacteals*, (from their being filled with a white fluid like milk, *lac*,) which are destined to absorb from the contents of the bowels those matters which by the digestive process have been rendered fit to nourish the body.

Such is a general sketch of the structure and relations of the alimentary canal. We have above alluded to certain subsidiary or assistant organs which are connected with it, and which now require a slight notice. These are the Spleen, Liver, and Pancreas.

The *Spleen* is a lenticular shaped dark blue spongy body, which is attached to the bulging extremity, or cardiac end of the stomach. Its chief peculiarities are, that it is furnished with very large blood vessels, that it has no duct, and therefore does not aid digestion by pouring any secretion into the stomach. The most probable conjecture concerning its use is, that it serves by its spongy texture as a reservoir into which blood may more freely enter, when the large veins and other vessels in the abdomen are subjected to pressure, or to other causes leading to irregular distributions of blood.

The *Liver* is a well known organ, and is the largest gland in the body. It lies horizontally on the right side, immediately below the diaphragm, and is protected by the anterior ends of the lower ribs. Its function is to secrete the well known greenish yellow fluid, the gall, or *bile*, which is conveyed from the liver by a canal called the *hepatic duct*. On the lower surface of the liver is situated a small pearshaped bag, the *gall bladder*, which is also furnished with a duct, called the *cystic duct*, which unites with the duct from the liver, and forms the *common biliary duct*. A great part of the bile goes directly from the liver by the hepatic duct into the bowel, but a portion regurgitates into the gall bladder, and is perhaps slightly altered during its residence there. The common biliary duct, as we have already noticed, opens into the duodenum at its lower angle.

Close beside the orifice of the common biliary duct we have the opening of the duct of the *Pancreas*, or Sweetbread. This is a gland very much resembling the salivary glands in structure. It lies lengthways across the body, with one end in the triangular enclosure formed by the

bendings of the duodenum. The fluid which it secretes very much resembles saliva, but is particularly rich in the animal principle called albumen.

Having thus sketched the structure of the digestive apparatus, we shall now offer a brief account of the function of Digestion. The sensations of Hunger and Thirst require to be noticed in entering on this subject, but on these preliminary points a very few words will suffice.

Of Hunger.—Hunger consists of two sets of phenomena, the local and general; the former being those of a peculiar sensation in the stomach, accompanied by a sense of dragging and dull pain; the latter being a general feeling of feebleness and exhaustion. If these sensations are not allayed by the taking of food, more painful contractions of the stomach come on, attended by an increased secretion of mucus, and subsequent evolution of gases within its cavity; and if abstinence is prolonged, the general phenomena become severe and intolerable. Upon what the local sensations of hunger depend it is not easy to determine. Nothing has been a more fruitful source of theory than the question as to the cause of hunger, but its discussion is of too speculative a nature for our present purpose, and would occupy much space without being practically useful. We may however observe, that it is the general rather than the local phenomena of hunger which engage our attention, and they are highly important as being an indication that the system at large is in want of additional nourishment. It appears to be well established, from the observations of many physiologists, that hunger is not felt until all the food previously taken has been digested; and it is observed to recur much sooner when the food has contained a small amount of real nutriment. The circumstances which tend to increase hunger are those which increase generally the activity of the bodily powers, and thereby promote the completion of the digestive process. Thus gentle exercise, cool air, a tranquil state of mind or moderate mental excitement, and a healthy state of the body

favour the appetite for food; whilst in general a sedentary life, heat, mental anxiety, and important derangements of the corporeal functions impair or destroy it.

If the appetite is to be considered as the proper indication that the system is ready to receive and appropriate to itself fresh nutriment, it is obviously wrong to burden the digestive organs with further supplies of food, before this natural monitor warns us that what was previously taken has been fairly digested. But if it is an error to anticipate the demands of the system by supplying food too soon, it is no less wrong to delay it beyond the time indicated by nature. If abstinence is protracted much beyond the usual time, the natural and healthy phenomena of appetite first become diminished, and then are soon succeeded by others of a morbid character. If the fasting be still further prolonged, the system falls into a condition almost totally unfitting it for the reception of food, and it is well known that a further continuance of privation soon leads to a fatal result. The periodical return of hunger, with which most people are practically acquainted, is probably mainly due to habit, and is the result of that arrangement by which, in civilized countries, a particular period of the day is generally adopted for taking a certain amount of nourishment.

It is obvious, in reference to all this, if hunger may in general be regarded as a proper indication of the wants of the system, that he who would preserve his health and vigour entire, and, above all, the invalid who would restore his strength, exhausted by disease, will best attain his object by observing a system of regularity, which will ensure his having his food ready for his use at the time that his body is in the condition best fitted to receive and assimilate it.

Of Thirst.—Besides a continued waste of the solids of the body, requiring fresh supplies of food, and thereby leading to the phenomena of hunger, there is likewise going on at all times an expenditure of the fluids of the

body, which requires to be compensated for, and which, when it has gone to a certain length, gives rise to *Thirst.* This, like hunger, has both local and general effects. The former are dryness and a burning feeling of the mouth and throat; the latter are nearly the same as the general effects of hunger, but are far more intense and intolerable. The privation of food may be borne for a considerable while, but the want of drink, and above all, the two combined, are, even to the stoutest frame, insupportable after a very short time. Like that of hunger, the proximate cause of thirst has been the subject of much discussion. Though we cannot say that the explanation is very lucid, it may safely be stated to be connected with a peculiar state of the nerves of the stomach and gullet, at the same time that there is a want of the due secretion from the lining membrane of the throat, which however is probably rather an effect than a cause of the peculiar state of the nerves. Though referred to the throat, it is probable that it has its origin, sometimes at least, in the stomach, for thirst can be appeased by the introduction of fluids into the stomach, though they do not touch the gullet at all; as, for instance, in some cases of wounds of the throat, where the patient has been supplied with fluids through a tube, and where thirst has been appeased without the liquids touching the throat at all. Thirst has also been allayed in cases of shipwreck, by the application to the skin, of jackets and cloths wet with sea water; but whether the relief here experienced is to be ascribed to the absorption of fluids by the skin, or merely to a peculiar impression on the nervous system, it would be foreign to our purpose to discuss. Thirst is best appeased by fluids which are moderately stimulant or nutrient, probably because these are best fitted to make some impression on the nerves of the stomach, or to produce some effect on the system generally. Water gives only temporary relief, by moistening the mouth and throat. The connection of thirst with the stomach is further shewn by the fact that certain articles of

food, generally those which are least digestible, in many persons give rise to this sensation.

Of the Digestive Process.—The food which appetite prompts us to take, before being subjected to the digestive process, is rendered more easily swallowed and more digestible by *mastication*, or chewing. Generally speaking, vegetable substances should require to be more acted on by the teeth than animal matters, though from the culinary processes which they have undergone, those vegetables employed by man are more easily broken down. It is during mastication that the food is mingled with the saliva, the uses of which were formerly alluded to. The food being swallowed comes within the action of the stomach, and begins to undergo the first and most important part of the digestive process.

Upon the introduction of food, or even of some non-alimentary substances, into the stomach, a particular secretion, well known by the name of the *Gastric juice*, begins to be poured out into that organ. This singular fluid, under such circumstances in healthy subjects, is uniformly possessed of *acid* properties, and chemical analysis has shewn this to be due to the presence of a certain amount of *Muriatic Acid** and *Lactic Acid.*† The acid juice is not formed in the stomachs of fasting animals, and therefore its presence is not, as some have supposed, the cause of hunger, but its secretion is determined by the ingestion of foreign matters into the stomach, and its quantity is greatest when the substances swallowed are rather indigestible. Its solvent powers are its most remarkable properties, and are of such a nature as not to warrant the supposition that they are owing to the chemical agency of

---

* This acid in a concentrated form is well known as *Spirit of Salt*.

† This is somewhat similar to, and was long confounded with *Acetic Acid*, or vinegar.

the acids contained in it, but appear to be quite peculiar to itself. It can act on digestible matters out of the body as well as in the stomach; it acts on substances in themselves indigestible, and when accidentally present in the stomach at the time of death, it corrodes this organ itself. It is also possessed of a remarkable amount of antiseptic power, that is, it prevents substances from becoming putrid. It would appear from some very recent experiments of a German chemist, Wasmann, that from the stomachs of animals there can be procured a peculiar animal matter, which he calls *Pepsine*, (digestive principle, from the Greek *Pepto*, I digest) which even when dissolved in a large quantity of water, has a remarkable power of acting on digestible matters in the same way that the gastric juice does; but his experiments have not been sufficiently corroborated to warrant our ascribing the solvent powers of the gastric juice solely to it.

The secretion of the gastric juice appears to be promoted by rest, and most people are naturally inclined to take some repose immediately after eating. Though slight exercise does not interfere with the process of digestion, or may even in some cases promote it, violent exercise certainly retards or hinders it. This has been proved by direct experiments on animals.

The process of digestion does not appear to begin immediately on food being taken, but in a short period of time, perhaps in about half an hour, that portion of the contents of the stomach which lies next its walls, becomes softened, and is gradually reduced to an uniform pultaceous mass, generally of a greenish gray colour, which has been denominated *Chyme*. As digestion goes on, the chyme, by the contractions of the muscular fibres of the stomach, accumulates towards the pylorus, and is by successive portions ejected from the stomach into the duodenum, and this goes on until the whole of the food has undergone this change. During this process, the food is subjected to a certain degree of mechanical action, by the constant con-

tractions of the stomach. This mechanical process is comparatively very slight in man and other animals furnished with membranous stomachs ; but in graminivorous fowls, whose food is hard, and who have no teeth wherewith to grind their food, the action of the muscular stomach, or gizzard, is of a powerful nature, and these birds are, by a beautiful provision of instinct, led to swallow small pebbles, which help to grind their food, and so to supply the place of the teeth of other animals. The contractions of the stomach vary with the digestible and nutritive qualities of the food ; substances which afford least nutriment, such as vegetables, being generally soonest expelled from the stomach. The whole of the food is seldom entirely dissolved in the stomach, but part escapes unchanged into the duodenum, where it undergoes still further changes. The period when the whole of a meal has passed from the stomach, varies exceedingly with the qualities of the food and the gastric powers of the individual. In man, in some cases, the whole of a copious mixed meal seems to have passed the pylorus in three hours, whilst in others four, five, or even six hours appear to be required for its complete transmission.

When fresh portions of food are introduced into a stomach containing half digested aliments, they are very apt to escape digestion altogether, and eventually to prove troublesome. This is ascribed by some authors to their falling into the centre of the mass, and thus not becoming properly exposed to the gastric juice. But other writers with more probable correctness maintain, that newly taken food is by the movements of the stomach mingled with what it already contains, and that the disturbance of digestion is owing to the inability of the stomach to secrete a sufficient quantity of gastric juice to act on additional aliment. Whatever be the theory, the fact is most important, that fresh food, taken before the complete digestion of a previous meal, is apt to prove pernicious.

The nature of the chyme varies much, according to the

qualities of the food taken. It does not contain real *albumen* or *fibrine*, unless these have formed part of the food, and, therefore, does not appear chemically to resemble the blood which is afterwards to be formed from it. Some globules, however, have been found in it, which have been termed *incipient albumen*, but their source is not well ascertained.

The food having passed the pylorus, undergoes some further changes in the duodenum, and is there mixed with the pancreatic juice and bile. Albumen, probably derived chiefly from the pancreatic juice, can now be detected in the chymous mass in larger quantity. An alkaline matter, free soda, contained in the bile, combines with and neutralizes the acid of the gastric juice, and from the colouring matter of the bile, the mass has now become yellow. It is at this stage of the process that the most remarkable and mysterious of all the phenomena of digestion occurs. On the surface of the chyme there is now found a peculiar fluid, more or less milky in appearance, which is found to consist in great measure of white globules suspended in a clear liquid. This fluid is called the *Chyle*, and it is this which is destined to be converted into blood, and so to nourish the body. Some circumstances attending its formation have been cleared up by recent investigations, but still the essential cause and manner of its production may be said to be unknown. It is white like milk, and, with the exception of its colour, possesses many of the properties of the blood; for it coagulates like blood when drawn from the body, and its essential chemical constituents are like those which are found in perfect blood. It is taken up by the lacteal vessels formerly mentioned, and is by them carried away from the intestines, passing in its course through a series of small glands situated in certain folds of the peritoneum. At length these lacteal vessels all unite into one large trunk, which is called the *Thoracic duct*. It passes upwards along the left side of the back bone, from the belly through the chest, to the lower part of

the neck, where it empties itself into one of the largest veins of the body, close behind the collar bone; and thus the nutrient matters separated from the food by the digestive process become mingled with the blood, and are soon rendered fit for being assimilated to, i. e. united with, the living textures of the body.

We now return to trace the course of the remainder of the food. As it passes along the small intestines, the chyle is gradually taken up from it by the lacteals, and is nearly all gone by the time it reaches the lower end of the lesser bowels. It now passes into the head of the large gut, the cœcum, and there it appears, especially in herbivorous animals, to undergo another slight and final process of digestion, and becomes again slightly acid, a property which it had lost during its passage along the small intestines. What now remains is nearly all excrementitious, i. e. it cannot serve for the nourishment of the system, and is destined to be expelled from the body. Any nutritive or watery parts which remain are taken up as the mass passes along the great intestine, and when it reaches the lower end of the alimentary canal, it has generally acquired a solid consistence, and is ejected from the body.

Of Aliments.—The substances used by man as articles of diet consist partly of solids and partly of fluids. This great natural division suggests the propriety of arranging aliments under the heads of *Food* and *Drink*, to which we add a third division, *Condiments*, or substances which, though not in themselves nutritious, are yet from the nature of our food, necessary or useful in promoting its digestion. We have not space, however, to devote to a complete consideration of this subject in all its bearings, and therefore limit ourselves to a few observations on food.

All the substances employed by man as articles of food belong either to the animal or vegetable kingdom, no mineral substance being capable of assimilation except water. The unctuous clay mentioned by Humboldt as being eaten by the Ottomaques is only a seeming excep-

tion. It either only appeases hunger temporarily by mechanically distending the stomach; or if it does really nourish them, it is probably strongly impregnated with organic matters. The object to be held in view in the selection of food, is to obtain a supply of nutriment which will repair the waste that continually goes on in the body. This it is obvious cannot be done, except by the addition of matters of the same nature as those of which the tissues of the body consist. All organized bodies chemically considered, consist of certain substances which have hitherto resisted decomposition, and which have therefore been termed by chemists *Elementary* or *Ultimate Principles*, or *Simple Bodies*. Of these, *Carbon*, *Hydrogen*, and *Oxygen*, in various proportions, enter into the composition of all organic matters, and, generally speaking, vegetable substances consist of these alone. Most animal matters contain a fourth element, *Azote* or *Nitrogen*,† but to these general laws of constitution there are numerous exceptions in both kingdoms of nature. Besides these, there are found in organic bodies some other elementary principles, which, however, do not seem essential to their constitution. Among these may be mentioned, *Sulphur*, *Phosphorus*, *Sodium*, *Calcium*, *Magnesium*, &c. It appears that a proportion of all the four *essential* ultimate principles first mentioned, is required to constitute food which will answer for any length of time to maintain life, though the absence of one of them may be borne for a short while. Nitrogen is the only one with regard to which this can be fairly tried, and it appears from experiments made in France, that its presence in the long run is necessary for the support of life, though for a short while, animals may be kept alive on unazotised food, i. e. food which contains no nitrogen.

† For an account of the particular nature and qualities of these and other elementary bodies, we must refer to the ordinary works on Chemistry.

It appears, however, from a general view of the organic world, that a very elaborate organization would be required, if the higher animals were obliged to assimilate these elements in their simple or ultimate condition; and therefore we find a beautiful law of nature in force, by which the lowest forms of the organic kingdom furnish nutriment to those higher in the scale, and these again to beings of a still higher organization, by which arrangement these elements are presented to them prepared in such a manner, as to render their assimilation practicable without great complexity or minuteness of organization. The ultimate principles, then, are thus presented to the higher animals in certain states of combination, which are of great variety, many of them, indeed, apparently of the same chemical constitution, and others varying by very slight differences of proportion only, but all of them possessing some distinctive peculiarities or properties. These compounds, or states of combination of the ultimate principles, have been called by chemists *Proximate Principles*, examples of which, from both kingdoms of nature, are familiar, in *Starch*, *Oil*, *Sugar*, *Albumen*, *Gelatine*, *Fibrine*, &c.

We have already stated that to form an aliment fit for the continued use of man, we require to have a certain amount of all the essential ultimate principles present. We, therefore, in our food, require a mixture of those proximate principles whose composition fits them for fulfilling this end. The composition of milk, a fluid destined to nourish the young animal before it is able to provide food for itself, has been aptly cited in illustration of this proposition. It contains two substances, *Butter* and *Sugar of Milk*, which abound in Carbon, Oxygen, and Hydrogen, and a third, *Caseum*, or curd, which abounds in Nitrogen. We are able to imitate this combination of different proximate principles, that is, to form a diet proper for man, by using an artificial admixture of those substances in which particular elements preponderate. Thus, by employing vegetables as food, we obtain a diet chiefly consisting of

principles abounding in Carbon, Oxygen, and Hydrogen, and we complete its fitness for our continued use by adding to these a certain proportion of animal matters, which supply us with Nitrogen. A diet consisting of either animal or vegetable matters exclusively, is therefore not that which is most proper for man, but a certain combination of both is necessary. For a person in health, it is probable, that the most eligible proportions are nearly one-third animal and two-thirds vegetable food.

The comparative nutritiveness, or power to repair the waste of the body, varies not only with the different classes of proximate principles, but even with the different substances of the same class, and their varieties in this respect are made known to us by observation. Animal food, or rather those substances, of whatever origin, which contain nitrogen, are more nutritive, *i. e.* support the system better, than those which are unazotised. This has been said to be owing to their requiring less change to be effected on them, in order to assimilate them to the textures of the body, which nearly all contain Nitrogen; but this does not appear to be a very satisfactory explanation, for the most perfectly animal substances, when introduced into the stomach, undergo before their assimilation, as complete a change during the digestive process, as those which have a truly vegetable origin and composition. The fact, however, is of great importance in a practical point of view; for the degree of nutritiveness is a matter of great importance in determining the quality of food to be used in different circumstances. For example, when we wish rapidly to restore strength to a person who has been the subject of an exhausting disease, we allow a copious supply of animal food, on account of its more highly nutritive qualities; when, on the contrary, we wish to reduce a plethoric or corpulent person, we make the food to consist chiefly of vegetable matters, which are less nourishing.

But, in considering the qualities of food, we must take into account not only the nutritiveness of the aliments, but

also their comparative digestibility. It must be borne in mind, that the terms nutritive and digestible are very far from meaning the same thing; and the consideration of this, in a practical point of view, is of the highest importance. A substance may be easily acted upon by the digestive powers, and yet not yield a copious or highly nutritive chyle; whilst, on the contrary, a substance may require the strongest gastric agency to digest it, and yet yield a very abundant supply of nutriment. The terms light and heavy, are those in common use to express the greater or less digestibility of aliments.

A great variety of experiments have been made to ascertain the circumstances which regulate the digestibility of different aliments; but these are too minute for detailing here. With respect to individual articles of food, this depends chiefly on the kind of proximate principles which they contain; and with respect to proximate principles themselves, their relative digestibility forms in each case an ultimate fact in their history. Thus we know that starch, and substances which consist chiefly of it, are easily digested; and that oil and oily matters are very indigestible; but we do not know any reason why this should be, and we regard it as an ultimate fact with respect to each.

A very important consideration relative to the digestibility of aliments, is that of the form in which they are taken. Man, as everybody knows, does not in general take his food in its natural condition, but submits it to certain processes, chiefly by the agency of fire, by which he renders it more agreeable to his taste, and better adapted for yielding him nourishment. Hence has arisen the practice of *Cookery*, which originally was designed to serve both these important ends in an equal manner, but which, in its modern perfection, seems calculated in general to please the palate, at the expense of the digestive organs. Man, however, both in his civilized, and still more in his barbarous condition, consumes many articles of food raw.

Few animal matters in this country are eaten in this state, but many vegetables are, and these are to be ranked among the substances which are least of all fitted for feeble stomachs. Salads, for instance, undergo little change in the stomach, and not much more in the intestines, and the skins of fruits and seeds are almost always voided unchanged. Vegetable substances, when cooked, require to be very thoroughly exposed to the action of heat, whilst animal matters, on the contrary, are much deteriorated by being overdressed. The manner in which the heat is applied has likewise a considerable influence in modifying digestibility. We would gladly have said something here in detail respecting individual articles of food, but our limits prevent us from attempting this.

Before quitting this subject, we may deduce from the foregoing statements the following practical conclusions:

That it is best to live regularly, to take food only when hunger prompts us, and not to use more food than is required to allay this sensation.

That we should never take food, until that which has previously been taken, has had time to be digested.

That we should not take violent exercise immediately after eating.

That a certain proportion of animal and vegetable food taken together is that which is best adapted for our wants, and consequently that we should not use either in excess, except in particular cases of disease.

That we should avoid all substances which experience has shown to be less easily digested either by our own or by other stomachs.

And that our food should be cooked simply.

We have thus viewed the process of Digestion in most of its more important aspects. We have seen the structure and mechanism of the organs framed for the performance of this function; we have observed the manner of their action, and have noticed very generally the sources from which nutriment is drawn for the supply of the wants of

our bodies. We have seen the food undergoing a series of remarkable changes, in the course of which there was separated from it a vital fluid closely allied in properties to blood, and which we found to be eventually mingled with the blood already existing in the body. This leads us, therefore, now to consider the blood; the changes which it undergoes in the body; and the manner in which it is carried through all parts of the frame; in short, the functions of Circulation and Respiration.

OF CIRCULATION.

Of the Blood.—This is a fluid of a peculiar red colour, which is well known to circulate freely through all parts of the body. When regarded with the naked eye, as it flows from a cut for example, it appears to be a thickish homogeneous fluid; but if observed under a good microscope, it is found to consist of numerous small globules of a dark colour, suspended in a clear liquid. The mixture formed by the globules and clear fluid is rather heavier than water, and as it issues from the body it has a temperature of about 98° of Fahrenheit.

It is pretty generally known, that when blood is drawn in a copious stream from an animal, and is allowed to stand for some minutes, it coagulates,—that is, it separates gradually into two portions,—a dark red solid mass, called the clot, or *Crassamentum*, and a greenish fluid, somewhat resembling whey, called the *Serum*. The clot is found to contain the globules formerly mentioned, and by carefully washing it with repeated quantities of cold water, we may separate it into two parts;—first, a tough, elastic, stringy mass, which is the animal proximate principle *Fibrine* nearly pure, and secondly, the red colouring matter of the blood, which has been called *Hæmatosine*, or *Hæmatine*.

The serum, again, is found in chemical composition to resemble the white of an egg; for it contains a quantity

of *Albumen*, in virtue of which it is coagulated into a white opaque mass, when it is heated. If the coagulum thus obtained from the serum is allowed to stand for some time, it gradually shrinks, and expresses from it a small quantity of a fluid, called the *Serosity*, which contains chiefly a little animal matter and salts. We must not confound the serum separated during the coagulation of the blood with the clear fluid in which the globules are suspended when the blood is liquid; it must not be supposed, in short, that the liquid blood is merely the red globules suspended in serum; for, in fact, as we shall find immediately, the most important portion of the clot forms, when the blood is still liquid, a constituent of the clear fluid. But this will be better understood when we have considered these different portions of the blood somewhat more in detail.

Of the Red Particles or Globules.—If liquid blood diluted with serum, or a weak solution of sugar, is placed below a good microscope, the globules can be readily seen floating about in the liquid. A great deal of discussion has arisen as to their true structure, for appearances of very minute objects, under the microscope, are very apt to be deceptive; but the following seem to be the best ascertained facts as to their nature:—

They are not balls or spheres, but flat disks. In man, and other mammalia, *i.e.* animals which suckle their young, these disks are circular, but in birds, reptiles, and fishes, they are more or less oval. They have been aptly compared in form to a piece of money,—the chief difference being that, when viewed laterally, they are seen to be thicker in proportion to their breadth than a coin is. When accurately observed, it is easily seen that in the centre of each disk there is a dark spot, which has been regarded by some as an elevation, and by others as a depression. It appears to be, in fact, the *nucleus*, or central portion of the globule, which, as we shall presently see, is a distinct substance from the part which appears transpa-

ıent, and which is, in fact, the envelope, or outer covering of the particle. The size of the globules has been variously estimated by different microscopic observers; perhaps it is not far from the truth to say, that they vary in man from the 4029th to the 2637th part of an English inch. They are of very different sizes in different classes and species of animals. In frogs, they have been estimated to be from the 1107th to the 997th part of an inch. The two portions of which they are composed, the nuclei and the outer envelope, are very easily separated from each other. So long as the globules are in contact with serum, they are not altered, but remain entire; and the same thing holds when they are brought in contact with a dilute solution of sugar. But when plain water is poured upon the globules, they are instantly acted on; the outer envelope, which is the colouring part, is dissolved away, and, by careful management, the nuclei are obtained in the form of white granules, of about one-fourth the size of the original particles. The chemical nature of the nuclei is not quite determined. They consist of a matter somewhat allied to Fibrine and Albumen, but not strictly identical with either.

The red colouring matter of the envelopes demands a more particular notice. It is commonly regarded as a distinct animal proximate principle, and is called *Hæmatine*, or *Cruorine*. It is distinguished by being soluble in cold water, and if the solution is evaporated at a temperature not exceeding 122° of Fahrenheit's thermometer, it is obtained dry in the form of a blackish mass, which when rubbed in a mortar, forms a dark red powder. If, however, the solution is heated to any point above 160°, it is coagulated like Albumen, and is then insoluble in water. In its ultimate composition, it closely resembles Fibrine, but it is found always to contain a considerable proportion of *Iron*. This last appears to be an important, if not essential constituent of the colouring matter, but doubts are still entertained by many authors as to the presence of

Iron being the cause of its peculiar colour. The most remarkable property of Hæmatine is its tendency to change its colour from a dark to a bright red. This, as we shall afterwards see, is a fact of great interest and importance. All that we think it necessary to say at present is, that when it is got from blood drawn from a vein, it is of a dark red tint, somewhat inclined to purple; but when it comes in contact with the atmospheric air, or with oxygen gas, the most important constituent of the air, it becomes of a bright scarlet hue; and this change is likewise produced on it by the contact of certain salts, such, for example, as common salt, saltpetre, and sulphate of soda or Glauber's salt.

Of the Fluid Portion of the Blood.—It has often been supposed, that the fluid portion of the blood, in which the globules are suspended, is identical with the Serum which separates when blood coagulates. But this is now known to be an error. The fluid portion of the blood, or *liquor sanguinis,* as it has been called, is essentially different; for when the blood is moving in the bloodvessels, this clear fluid contains in solution the Fibrine, which constitutes the greater part of the clot which forms when the blood is removed from the body. If by any means we can separate the red globules before the blood has time to coagulate, we shall at once perceive the difference between the fluid of the blood and the serum. This can be shown by a simple experiment with the blood of a frog, first made by Professor Muller, which we shall relate shortly as the best explanation of the fact:—If the fresh blood of a frog is caught on a filter, the globules are all retained, and the entire clear fluid passes through. If this is caught in a watch-glass, and examined, it is found that it soon coagulates, and forms a distinct clot, which, however, is white, because it is now no longer mixed with the red colouring particles; and as the fibrine, which is the cause of the coagulation, shrinks, the serum is gradually expressed from it, and separated. By this simple experiment, there-

fore, we see that the blood consists of three essential portions,—the Red Globules separated by the filter, the Fibrine dissolved in the liquid, and this liquid the Serum, from which the Fibrine separates by coagulation. In short, then, the blood may be regarded as a solution of Fibrine in Serum, having red globules suspended in it. We may mention, that the reason why the above experiment cannot be made with the blood of man is, that the globules of human blood are so much smaller than those of the frog, that they pass through the filter with the fluid portion.

The blood is believed, by a large proportion of physiologists, to be possessed of vitality, that is, to be endowed with life. The discussion of this question, however, would lead us into speculative inquiries, for which we cannot afford space. If the blood is really endowed with life, it is so only when moving in the blood-vessels of a living animal, and loses this quality on being withdrawn from the body. In accordance with these suppositions, many persons regard the coagulation of the blood as being owing to the extinction of its vitality. But we have said enough of the general properties of the blood, and we now come to consider the mechanism by which it is transmitted or circulated through the body.

Of the Powers which move the Blood.—It is well known that the blood in passing through the body is circulated, as the phrase is, that is, it passes away from the heart in one direction, and returns again towards the heart by another route. The more important truths relative to the circulation of the blood were unknown till the year 1619, when they were explained by our immortal countryman, William Harvey. The organs by which the blood is circulated are the Heart and Blood-vessels, forming, when taken conjointly, what is called the *Vascular* or *Sanguiferous system.* The Blood-vessels consist of two great sets, the Arteries and Veins; it is by the former of these that the blood is carried out from the heart, by the latter it is brought back to that organ. We shall briefly describe in succession, the Heart, the Arteries, and the Veins.

Of the Heart.—This important organ is a hollow muscular body of a well known pyramidal shape, lying in the chest towards the left side of the body. It is surrounded by a loose membranous bag called the *Pericardium.* This membrane consists of two layers. The outer one is tough and fibrous, is connected at its upper part with the heart and large vessels issuing from it, and at its lower part, attached to the Diaphragm or transverse muscle separating the cavity of the chest from the belly. It thus serves, to a certain extent, to preserve the heart in its proper situation, in whatever position the body may be placed. The inner layer of the pericardium is one of the serous membranes, the general nature of which was formerly mentioned when speaking of the Peritoneum. It not only lines the whole of the inside of the pericardium, but it is reflected over the surface of the heart itself, and closely invests it. The outside of the heart, and the inside of the pericardium are thus both covered with this serous membrane; and from its surfaces being always smooth and moist, the heart moves freely within the pericardium, when it contracts or expands. The heart itself is pyramidal, the *apex*, or point of the pyramid being directed downwards and forwards towards the left side. Its walls consist of several layers of strong muscular fibres, which run obliquely round it in various directions. On the surface of the heart we observe two grooves or furrows, one running transversely across the heart, and separating its base or flat end, from its lower or pyramidal portion. The other groove runs perpendicularly along the heart from its base towards its apex, and thus separates the right from the left side of the organ. These grooves indicate the division of the heart into four distinct cavities. The two upper, at the base or flat end, are called the *Auricles;* the two lower at the apex of the heart bear the name of *Ventricles.* As each of these cavities is distinct, we shall briefly describe them separately.

The *right auricle* forms the right and anterior part of

the base of the heart. It, as well as the left auricle, has received its name, from a portion of it which is prolonged upwards into a loose hollow appendage, somewhat resembling a dog's ear. It is a hollow muscular cavity with thin walls, separated on the left side by a thin partition from the left auricle. In this partition we find an oval depression, which before the birth of the animal was open, and caused the two auricles to communicate directly with one another. There are three openings into the right auricle. Two of these are the mouths of two large veins, which we shall mention hereafter, the other is the *right auriculo-ventricular opening*, or aperture by which the right auricle communicates with the right ventricle.

The left auricle makes up with the right auricle the remainder of the base of the heart. It has the same general appearance and structure as the right auricle, except that it lies to the back and left side of the heart. It has five openings into its cavity. Four of these belong to the pulmonary veins, bringing blood from the lungs. The other is the left auriculo-ventricular opening, and establishes a free communication between the left auricle and left ventricle.

The right ventricle forms the right half of that portion of the heart which lies below the transverse groove formerly mentioned. It is a triangular cavity, with muscular walls thicker than those of the auricles, and extending from the right auricle to nearly the apex, or point of the heart. When we open it in front and examine its interior, we find that it is marked within by several strong detached bundles of muscular fibre, some of them furnished with delicate tendons or sinews, which are attached to a valve, the nature of which we shall describe presently. There are two openings into the right ventricle; one of these is the auriculo-ventricular opening formerly noticed, by which it communicates with the right auricle. This remarkable opening if viewed from the ventricle, is seen to be furnished with a valve, which is a structure of great impor-

tance. It is called the *Tricuspid valve*, from its having three points. There are three triangular folds of the membrane which lines the cavities of the heart, they are attached by their bases to the edge of the auriculo-ventricular orifice, whilst their points hang loose into the cavity of the ventricle. They can fold back freely into this space, and, therefore, allow the blood to pass readily from the auricle into the ventricle ; but they are prevented from folding back into the auricle by the little tendons formerly noticed, and therefore, when any blood attempts to rush from the ventricle to the auricle, they hinder this from occurring, because they stretch across the auriculo-ventricular opening and close it up. The other opening into the right ventricle, is a large blood-vessel going to the lungs called the *Pulmonary artery*. This will be noticed hereafter; but in the meantime, all that requires to be observed is, that its orifice is likewise protected by a set of valves called from their half-moon shape, *semi-lunar valves*, which, whilst they allow blood to pass freely from the ventricle into the artery, prevent it from regurgitating in the opposite direction.

The left ventricle forms the remainder of that portion of the heart which lies below the transverse groove. Its walls are thicker than those of any other portion of the heart, and extend from the lower part of the left auricle to the apex. Its internal appearance is very similar to that of the right ventricle, being marked by the fleshy columns, and having likewise two openings into the cavity. One of these openings is the *left auriculo-ventricular orifice*, which like that of the right side is furnished with a valve. In this instance, however, the valve has only two points, and has hence, from an obvious comparison, been termed the *Mitral valve*. The other opening is the orifice of the great artery the *Aorta*, by which blood is sent to all parts of the body. This is likewise furnished with three semi-lunar valves similar to those which guard the mouth of the pulmonary artery. Such are the cavities of the

heart, the centre of the circulation. All that we shall add to this short description is, that they are lined throughout with a fine smooth membrane, which, as we shall find, likewise lines the interior of the blood-vessels, which we shall now briefly describe.

Of the Blood-vessels. These are divided into two great sets, *Arteries* and *Veins*, each of which requires a brief separate consideration.

Arteries were so named by the Ancients from two Greek words signifying " to carry air," because from their being always after death found empty, they were supposed to convey some aerial fluid. They are cylindrical tubes, highly elastic, but at the same time so firm in their texture, that when cut across, the ends of the divided portion generally remain open. They consist of three coats or tunics. The *outer coat* is composed of strong cellular tissue, which confers upon these vessels their great strength and firmness. *The middle coat* consists of numerous circular fibres, highly elastic, and also possessed of some power of contraction; they are not, however, admitted to be real muscular fibres. The *inner coat* is identical and continuous with the serous membrane which lines the heart.

It is of course not our province to describe here all or any of the arteries of the body individually. They may all be regarded as branches of the great artery of the body, the *Aorta*, which arises from the left ventricle, passes upwards high in the chest, and then bending backwards in the form of an arch, passes downwards along the spine. In its course it gives off large branches to the head and arms, and smaller branches to the various organs in the chest and belly, and then at the lower part of the back bone splits into two large divisions, which carry blood respectively to the right and left lower extremities. As the arteries subdivide to supply the various organs and tissues of the body, they gradually diminish in size like the branches of a tree, until their ultimate ramifications are so minute as to be invisible to the naked eye. But

to these very small vessels we shall return, when we have said something of the other class of blood-vessels.

Of the Veins. These, like the Arteries, are ramified through every part of the body, and generally a vein of corresponding size accompanies each of the arteries. The veins have three coats, similar in nature to those of the arteries, but very slightly if at all elastic, and not at all firm in texture, so that the veins when cut across always become collapsed and flaccid. The most important difference in structure betwixt arteries and veins is in the inner coat of the latter, which in many parts of their course, especially where the vessels are in a dependent position, as in the legs, is formed into small valves of a semi-lunar form, which permit the blood to flow readily towards the heart, but prevent it from going back in a retrograde direction. The veins have generally a deep blue colour, which is easily observed in those which are superficial, as on the legs or at the bend of the arm. As the veins carry blood from the distant parts of the body towards the heart, we shall best understand their distribution by tracing them, in the direction opposite to that in which we followed the arteries. Viewing them, therefore as arising in the substance of organs and tissues by most minute ramifications, we find them gradually coalescing, and forming larger and larger branches; these again successively unite, and they at last terminate in two great trunks called the *Venæ Cavæ*, the one bringing the blood from the lower parts of the body, the other conducting it from the head and upper extremities, and both pouring their contents by two openings, formerly noticed, into the right auricle of the heart.

We have already said that the arteries carry out blood from the heart, and the veins bring it back again, and we have mentioned that blood occurs in the body of two different colours, one scarlet, the other deep purple. The differences of these kinds of blood will be more intelligible when we have said something about respiration. In

the meantime we may mention that the scarlet blood is found in the arteries, and the dark blood in the veins, hence these kinds of blood have been named respectively arterial and venous blood.

The passage by which the blood, going out by the arteries, finds its way to the veins, to be returned by them to the heart, is by the minutest ramifications of each set of vessels. These very small ultimate divisions of arteries and veins are called *capillaries*, a Latin term, indicating that their size is comparable to that of hairs. These are vessels of the greatest physiological importance. It is in them that the important processes of nutrition and secretion are carried on; it is in them that the blood undergoes its mysterious change from the arterial to the venous hue; and they are likewise the essential seat of some of the most important morbid changes that occur in the body, as, for example, inflammation. Much discussion has arisen as to the real nature of the capillaries;—whether they are chiefly arteries or veins;—whether they have the power of contracting;—how many coats they have, or whether they have any coats at all;—or whether they are not rather spaces left between the fibres and other portions of tissues. But these topics are too speculative for our present object. It is enough for our purpose to say, that capillaries exist wherever blood finds its way; and, indeed, the greater bulk of many important organs consists in great measure of capillary blood-vessels. They are very minute, sometimes so much so as not to admit the red globules of the blood, but only permitting the passage of its fluid portion. This is well seen in the case of the white part of the eyeball. When this is healthy, its blood-vessels are so small that only the colourless portion of the blood finds its way through them. But when the eye is inflamed, the coats of these vessels becoming weaker, they are readily distended by the impulse of the blood against them; they thus become enlarged, the red globules find their way into them, they are thus rendered red and visible to the naked eye, and

the inflamed part has now assumed the appearance which is known by the common phrase of being "bloodshot."

These various blood-vessels, which have thus occupied our attention, are destined to carry blood to all parts of the body, for the purposes of carrying on nutrition and other important functions, and they are commonly said to form the general or *Systemic circulation.* There is, however, another circulation of blood, quite distinct from this, which, as it is carried on by a separate set of vessels, requires a separate consideration. We mean the circulation through the lungs, or *Pulmonary circulation*, which is maintained for purposes connected with the great function of Respiration. The vessels of the Pulmonary circulation are the Pulmonary artery and Pulmonary veins, which have already been casually mentioned in connection with the heart.

The *Pulmonary Artery* arises, as we formerly mentioned, from the right ventricle of the heart, where its orifice is guarded by three semi-lunar valves. On leaving the heart, it immediately passes backwards, and divides into two great branches, one going to the right, the other to the left lung. In the lung it quickly subdivides, and eventually forms a congeries of capillary vessels, which ramify every where through the substance of the organ. Tracing them onwards, we find them, as in the systemic vessels, reappearing in the form of minute veins, which gradually coalesce, and form four large trunks, called the *Pulmonary Veins*, two from either lung, and these pour their blood into the left auricle. There is one important fact to be attended to respecting the Pulmonary vessels, *viz.* that the blood carried by the Pulmonary Artery is venous, whilst that of the Pulmonary Veins is arterial; but the reasons of this difference will be better understood when we treat of Respiration.

Of the Course of the Blood.—We have thus so far described the Vascular System, or the organs which circulate the blood, Heart, Arteries, Veins, and Capillaries.

We trust that our readers are now in a condition to understand the course of the blood, and we think we can best explain this by starting from a fixed point, and tracing the blood through its career until we bring it back to the place from which we departed.

We may therefore suppose, that the red, or arterial blood has been brought by the pulmonary veins to the heart: it is now in a condition fitted to nourish the body, and to maintain the health of all its parts. The blood thus being poured into the right auricle, and that cavity being full, the first thing which occurs is, that the walls of the auricle contract, and the blood which it contains is forced into the left ventricle, through the auriculo-ventricular opening. Here it is not allowed to remain any length of time, for it is a well ascertained fact, that the presence of blood is the proper stimulus to the heart, and therefore, as soon as it is by the contraction of the auricle forced into the ventricle, this latter cavity contracts, and expels the blood from its interior. The mitral valve prevents the blood from being sent back again into the auricle, and therefore it is of course projected into the large artery, the aorta. As each successive portion of blood is ejected from the ventricle, it propels onwards the column of blood which already fills that vessel, and this shock or propulsion extends even to the minutest branches of the arteries. By this the arteries are dilated each time that the left ventricle contracts; and it is this periodic impulse in the arteries which gives rise to the pulse. Something more, however, than the mere impulse of the heart's action operates in moving the blood along the arteries. What we allude to is the elasticity of the arteries themselves. When the blood is thrown into a large artery, the aorta for instance, its coats are distended; but when the heart's impulse is over, the artery, being highly elastic, contracts again to its original diameter. It cannot force the blood back again into the ventricle, because the semi-lunar valves prevent this; it therefore helps to force the blood onwards

towards the capillaries, and thus, by the alternate action of the heart and elastic contraction of the arteries, the blood is moved on in a regular stream, until at length, in the capillaries, the action of the heart and that of the arteries alternate so regularly and equally with one another, that in these small vessels the current of the blood does not move by successive jets, as in the large arteries, but flows on in a smooth and uniform current.

We have now traced the arterial blood away from the heart into the capillaries, and we have seen it moving steadily on in these vessels. Whilst in the capillaries, however, it undergoes a remarkable change. It is during its passage through these minute tubes that it exerts its wonderful power of nourishing and adding to the various textures of the body; but having once done this, it is found to have lost its bright arterial hue, it has become dark venous blood, it is now no longer fit to carry on the nutrition of the body, and it is therefore to be returned to the heart, and towards this organ it travels along the veins.

The veins themselves have no power of contraction, and therefore, the motion of the blood through these tubes, must be owing to the same causes which propel it through the capillaries, viz. the combined action of the contractions of the heart, and elasticity of the arteries. We have seen that in the capillaries the motion of the blood is not by jets, but in a continuous stream, and the same is true as to the veins, the blood flowing through them in a steady and uninterrupted current. The valves of the veins contribute materially to the maintenance of the circulation, in consequence of their being so arranged, that blood can pass through them towards the heart, but not in the opposite direction. Any pressure applied to the veins must of necessity impel the blood onwards towards the heart, and thus muscular exertion tends to promote venous circulation, from the compression exerted on the veins by the muscles during their contraction.

It seems probable, however, that the flow of blood along

the veins is maintained not only by the powers which have been already mentioned, but further, that the heart itself, in dilating to receive fresh blood, helps to draw blood from the veins into its cavities by a kind of suction influence.

The blood thus travelling from the smaller towards the larger veins, finds itself at last in the two large vessels which we have described as opening into the right auricle. Into this cavity it rushes, and immediately the auricle contracts, and sends this dark venous blood into the right ventricle. This ventricle next contracts, and as the tricuspid valve prevents the blood going back into the auricle, it is necessarily forced into the pulmonary artery, and, by a series of steps similar to those which we have described in the case of the circulation through the rest of the body, it passes along the branches of the Pulmonary artery, through the capillaries of the lungs, and so into the Pulmonary veins. But during this transit it has undergone a remarkable alteration. Meeting with atmospheric air in the lungs, it has lost its venous colour, and is again of the bright arterial red. It is, therefore, again fitted to carry on the nutrition of the body, and is now to be conducted back again to the heart, in order that it may once more be distributed over the whole system. We shall describe this alteration of the blood in the lungs more in detail under the head of Respiration. In the meantime, we observe, that the blood, now again arterial, passes along the great Pulmonary veins, and so again reaches the left Auricle, which was the point from which we started in tracing its course through the body.

As we have been obliged to make a few digressive remarks in describing the circulation, we shall, for the sake of clearness, recapitulate the course of the Blood in a single sentence. Starting from the left auricle the arterial blood passes into the left ventricle, from that into the arteries, from these into the capillaries of the body, and here it becomes venous. Then it flows along the veins to

the right auricle, from that into the right ventricle, thence it is thrown into the Pulmonary arteries, passes through the capillaries of the lungs, again becomes arterial blood, and returns by the Pulmonary veins to the left auricle.

Although we have described these various contractions of the heart which propel the blood, as occurring in a regular succession, it must not be supposed, that if we were to observe the heart of a living animal in action, we should see four successive distinct contractions of its four cavities. On the contrary, we find that both auricles and both ventricles contract together, the contraction of the auricles preceding that of the ventricles by a few seconds. At the moment when the ventricles contract, the point, or apex of the heart is tilted forwards with considerable force, so that it strikes against the ribs, and produces a peculiar impulse, which every one must have noticed either in himself or in others. The contraction of the heart likewise is accompanied by certain sounds, which can be heard if the ear is applied to the chest of a living animal. Two sounds are audible, the first is dull and somewhat prolonged, and can generally be heard over a great part of the chest. It occurs at the same time with the impulse of the heart against the ribs, and almost at the same instant as the pulse at the wrist; it is, therefore, generally admitted to be caused by the contraction of the ventricles. The second sound follows immediately after the first sound; this is shorter and somewhat sharper, and after it has ceased, there is a short pause before the first sound is again heard. The cause of the second sound is not yet agreed upon by physiologists. It is not due to the contraction of the auricles, because that movement precedes the contraction of the ventricles, which we have shewn to be the cause of the first sound. One of the latest opinions advanced on this subject is, that it is caused by the flapping back of the valves of the auriculo-ventricular orifices, but we cannot hold this theory as having been fully established

There are many other points of great interest connected with the Circulation of the Blood, but upon these our space forbids us to enter.

Of Respiration.

We proceed now to give some account of a function to which we have already frequently alluded, *Respiration*, by which the blood, which has during its passage through the capillaries become dark and venous, and unfitted to nourish the body, is by exposure to the atmospheric air, restored to the bright red arterial condition, and is again rendered fit to maintain the various tissues of the body in a healthy state.

We shall adopt the same plan which we followed in treating of the circulation, describing first the organs of respiration, and then giving an account of the manner in which their function is carried on.

Of the Organs of Respiration.—Any structure by which the blood or nourishing fluid of the body may, from time to time, be brought into such proximity to the air, as to have its properties thereby renewed, constitutes a respiratory apparatus. There is an infinite variety of form observed in the organs of respiration in different classes of animals. Sometimes the respiration is effected by the direct contact of the atmosphere itself, whilst sometimes it is effected by means of water holding air mechanically suspended in it. In some of the very lowest forms of animal life, respiration seems to be carried on by the whole surface of the body; in Insects, the air is admitted by holes in the sides of the animal communicating with tubes which ramify through its whole body; in Fishes, the breathing is accomplished by the well known organs called gills, in which the blood circulates freely, and is exposed to the air which is held suspended in the water in which the animal swims. In their highest and most perfect condition, as in man and

quadrupeds, the respiratory organs assume the form of lungs, that is, of light spongy bodies made up of an immense series of tubes and cells, into which the air enters freely, and thus comes almost directly in contact with the blood, which circulates through the minute and highly ramified capillaries of the pulmonary artery.

The parts which we have to consider in describing the human organs of respiration, are the cavity of the chest or *Thorax*, the lungs, *Pulmones*, the windpipe, *Trachea*, and the top of the windpipe, the *Larynx*, which is the organ of voice.

The *Thorax*, or chest, is that portion of the trunk of the body to which the arms are attached externally, and within which are lodged the organs of respiration and circulation. In the skeleton, it is found to be a cavity of a conical form, with the apex of the cone upwards, but when, as in the living subject, the arms and shoulder blades are attached, it appears from the thickness of the shoulders to be broadest at the upper end. The chest is formed posteriorly by the spine, and on each side by twelve ribs, which are attached by joints to the spine behind, and the greater number of which are fixed in front by gristles (or cartilages) to the *Sternum*, or breast bone. Above, in the skeleton, the upper end of the cone is open, but in the living subject this is shut in by the muscles of the neck. Below, the chest is separated from the cavity of the belly by the flat transverse muscle, the *Diaphragm*, or midriff. In the spaces betwixt the ribs, there is a series of muscles called the *Intercostal* muscles, which are in two layers, the fibres of one layer running obliquely from behind forwards, the other, in the opposite direction. In consequence of this arrangement, these fibres, thus crossing each other diagonally, when they contract, tend to pull the ribs directly upwards. The ribs have an inclination forwards and downwards, so that when we perform the act of inspiration or drawing in the breath, we raise and throw forwards the anterior extremities of the ribs; and as the capacity of the chest is thus enlarged,

a vacuum is formed, into which the air immediately rushes. When, on the contrary, we perform the act of expiration, or letting out the breath, the diaphragm and the muscles forming the walls of the abdomen, which are all more or less attached to the ribs, contract, and thus pull the anterior extremities of the ribs downwards. The parts within the chest are thus compressed, and a great part of the air is expelled. The air enters the chest through the mouth and nostrils, which cavities communicate with each other behind the palate. It is at the back of the cavity of the mouth, and in front of the *pharynx* or top of the gullet, that the organ of voice, or *larynx*, is situated. This organ consists essentially of a cartilaginous box, open above and below, the upper orifice being formed of two ligamentous bands which run across it from before backwards. These are the *vocal chords*, the vibrations of which, from air passing out of the chest, give the sound of the voice. The little chink betwixt them, through which the air passes, is termed the *Glottis*. As we have mentioned that the larynx lies in front of the gullet, it is obvious that all the food and drink which we swallow must pass over it on its way to the stomach. In order, therefore, to prevent suffocation from the food falling into the larynx, there is a small cartilaginous valve of a triangular form, called the *Epiglottis*, placed to guard this orifice. Being attached by its base to the anterior edge of the larynx, just at the root of the tongue, and having its other extremity free, it folds down during the act of swallowing, closes the glottis whilst the food passes over it, and then rises as soon as the act of swallowing is performed. The larynx is suspended by a ligament from a small bone in the upper part of the neck, to the upper edge of which bone the tongue is attached by its root. The lower orifice of the larynx is continuous with the *trachea*, or windpipe. This is a tube composed of a series of cartilaginous rings, which, however, are not complete, being deficient at the back part, but they are bound together by a strong elastic fibrous membrane, so

that the windpipe is a tube possessed of some flexibility, but which is prevented from collapsing by the firmness of the cartilaginous rings. The windpipe runs down the front of the neck, passing into the chest behind the breast bone, opposite the upper part of which it divides into two main branches, called the *Bronchi*, one of which goes to the right, the other to the left lung. As we trace the bronchi through the body of the lungs, we find them immediately subdividing into innumerable branches, which at first are sufficiently firm in their structure to remain open when cut across, but which gradually lose their gristly texture, and become more and more thin and membranous. If we trace these bronchial tubes to their extremity, we find them terminating in innumerable rounded cells or vesicles, which, however, do not communicate directly with each other, the only opening into each cell being by the minute bronchial tube of which it forms the termination. Upon the walls of these cells the capillaries of the pulmonary arteries and veins ramify, so as to form an inconceivably minute net-work of vessels.

These vesicles constitute the greater bulk of the *Lungs*, which are two in number, one on each side of the chest. In the healthy state they have a deep blue colour; they completely fill the chest on each side, and are quite free and detached at every point, except what is called the root of the lung, where the air tubes and blood-vessels enter them, which is at the middle of their posterior margin, close to the spine. The lungs, from the air which they retain, are light and spongy, and float in water. When cut across, they present innumerable orifices of the air tubes and blood-vessels which have been divided by the knife. They, in fact, consist essentially of the branches of the air tubes, and of the pulmonary arteries and veins, bound together by a little loose cellular tissue. The air tubes, from the larynx to the pulmonary cells, are lined throughout with a tissue of the kind called *mucous membrane*, which secretes a slimy fluid. This, in its natural state, is

in very small quantity; but when the membrane has been somewhat inflamed, as in catarrh, the secretion is formed in large quantity, and constitutes the expectoration so troublesome in such cases. On the outside, each lung is invested with a serous membrane, called the *Pleura*, which covers them, and lines the inside of the walls of the chest, exactly in the way in which, as we formerly described, the peritoneum invests the bowels and the pericardium the heart. By means of this smooth glistening membrane the lungs play freely up and down during the respiratory movements of the chest. Such being the organs of respiration, let us now inquire somewhat into their function.

We have already indicated Respiration as being the function by which the venous blood is, by contact with the air, so altered as to render it fitted for carrying on nutrition and other important functions. The action which ensues is essentially chemical, and therefore we must offer a brief account of the chemical qualities of the atmosphere. The qualities of the blood have already been noticed.

The atmosphere in which we live, chemically considered, consists essentially of two gases, *Oxygen* and *Nitrogen* or *Azote*, the proportions being in a hundred parts, about twenty of the former and eighty of the latter. The nature of these gases we need not further comment upon, in relation to our present subject, than to state, that oxygen alone is capable of effecting that alteration in the blood which constitutes its change from the venous to the arterial condition. Air, therefore, to be respirable, *i. e.* to be able to carry on aright the function of respiration, must contain a certain proportion of oxygen. Hence an animal cannot live in an atmosphere of nitrogen, not because the nitrogen exerts any deleterious influence on the body, but simply because it is incapable of producing, when introduced into the lungs, the necessary alteration of venous to arterial blood. The atmosphere likewise contains a small propor-

tion of another gas, *Carbonic Acid Gas*, which, however, is regarded as rather an admixture than an essential component of the atmosphere, being present only in the proportion of about one part in a hundred of air. This gas, however, plays a very important part in the function of respiration, for, as we shall find immediately, it is uniformly produced by the act of breathing. It may be noticed that, chemically, this gas differs from oxygen and nitrogen, which are simple or ultimate elements, in being a compound body, it being made up of *Carbon* and *Oxygen.* It, moreover, differs from the other gases in its action on animals; for whilst oxygen supports life by maintaining respiration, and nitrogen proves fatal simply by excluding oxygen, carbonic acid, on the contrary, when breathed, is a positive poison, proving fatal by a *narcotic* action; *i. e.* by producing insensibility, as opium does.

Having thus stated the nature and composition of the air which we breathe, let us now briefly observe the changes produced on the air by the act of respiration. If we confine an animal in a limited bulk of air, it goes on breathing naturally for a while, but very soon respiration becomes oppressed, then is arrested altogether, and the animal dies. If we now analyse this air, we find that the oxygen has nearly or entirely disappeared; that the nitrogen remains almost unaltered in quantity; that a considerable proportion of watery vapour has been exhaled; and lastly, above all, that the place of the oxygen is supplied by nearly an equal bulk of carbonic acid.*

The decision of the point as to whether the quantity of

---

* It is very easy to shew, by a simple experiment, that carbonic acid is given off during the act of breathing. Let any one take a little clear lime water in a glass, and propel the breath through it by means of a small tube. The lime water will soon become turbid from the formation of the carbonate of lime, an insoluble compound of lime and carbonic acid.

oxygen consumed, and the amount of carbonic acid expelled during respiration are the same, is of very great importance in determining the manner in which this carbonic acid is formed. For it is well known from the researches of chemists, that when carbon and oxygen combine to form carbonic acid, the bulk of this gas evolved is exactly equal to the bulk of oxygen consumed in its production. When, therefore, experiments were published to shew that the oxygen consumed and the carbonic acid formed during breathing were in equal quantity, it was believed that in respiration the venous blood simply gave off carbon, which united with the oxygen of the atmosphere. But more recent experiments have shewn that the experiments, on which these conclusions were founded, were incorrect; that, in fact, more oxygen is consumed than equals the bulk of the carbonic acid, and hence it is believed that wherever the carbonic acid is formed, some oxygen passes directly into the blood to make it arterial. It might from this be inferred, that the fact merely was that some oxygen was consumed to form carbonic acid by direct combination with carbon in the lungs, and that then a small additional proportion was absorbed into the blood; but some late experiments have shown that carbonic acid is given off, when animals are made to breathe for a while pure nitrogen or hydrogen, where of course no oxygen could be present to form the carbonic acid by direct combination. Hence it is inferred that carbonic acid is formed in the venous blood during its passage through the body, and is merely given off at the lungs; whilst, at the same time, the oxygen which disappears directly combines with the blood to make it arterial. The great difficulty in adopting this view was, that no difference could be perceived between arterial and venous blood in the proportion of carbon which they contained, and that no carbonic acid could, by chemical means, be obtained from venous blood. But some very recent experiments, made in Germany have set this question at rest, by proving the im-

portant fact, that though both kinds of blood contain both oxygen and carbonic acid, yet that venous blood contains most carbonic acid, and arterial blood most oxygen. Hence, we repeat, that the most correct view of the nature of these changes in the air breathed, is that the carbonic acid is formed in the other parts of the body, that it is merely given off at the lungs, and that the atmospheric oxygen unites with the venous blood at the lungs and arterializes it.

Such being the changes produced by respiration on the air, let us now consider what alterations are effected in the blood. We have already repeatedly stated that the essential change wrought in the blood in the lungs is its conversion from venous to arterial. This is shewn at once by its alteration from the deep purple to the bright red colour; and when treating of the blood, we saw that this could occur out of the body as well as in the lungs. The other differences between venous and arterial blood are chiefly that the venous blood contains less fibrine than that which is arterial, probably because a portion of the fibrine of the latter is deposited in the tissues during the act of nutrition; and also, as appears from various considerations, because the exposure to the air during respiration has a tendency to aid the development of fibrine in arterialized blood. It also is believed from chemical researches, that arterial blood contains more oxygen and less carbon than venous blood. From these considerations, then, we infer that, during respiration, the venous blood loses carbon, acquires oxygen, has its proportion of fibrine increased, and is thus rendered better adapted for carrying on the nutrition of the body. But not only is arterial blood best fitted for maintaining the health of the various organs and functions of the body, but it is absolutely necessary for the preservation of life. If the access of fresh oxygen to the lungs is prevented, as by keeping an animal in a confined space, or by compressing the windpipe, death very soon ensues. The manner in which death

is thus produced is highly interesting in relation to our present inquiry. In an animal so circumstanced the circulation goes on naturally for a few seconds, arterial blood being brought to the heart, so long as any amount of oxygen remains in the lungs unconsumed. But very soon, from the want of oxygen, the blood passes through the pulmonary capillaries unchanged, and is sent to the heart in the venous state. It is in this condition propelled from the heart into all the organs of the body, and amongst the rest into the brain, and as soon as this venous blood reaches this important and delicate organ, the animal becomes insensible, and generally convulsed. But life is not yet extinct. What now follows is, that the capillaries of the lungs soon refuse to allow this unoxygenated blood to pass through them at all; and, therefore, blood being no longer delivered to the left side of the heart, the action of this organ ceases, and life is permanently extinguished.

On reviewing what has thus been said of the function of respiration, we observe the following facts: That respiration is a vital process, that is, it is essential to the life of the animal; that its object is to restore to the blood those qualities which render it fitted for supporting the body, and that for its proper performance we require air of a certain quality, containing a due proportion of oxygen gas, which we may mention from this circumstance received after its discovery the appropriate appellation of *Vital air*.

We have here some important subjects worthy of consideration in a practical point of view.

It will be obvious from what we have said respecting the mechanism of the chest, in relation to respiration, that any thing which interferes with its full expansion must be hurtful; we need hardly say, that modern dress, especially that of the female sex, is framed upon principles very little in accordance with the structure of the parts which it envelopes. The most expansible portion of the chest is its inferior part, and this is precisely the portion of the body which it is the object of many votaries of fashion to reduce

to the greatest possible tenuity. This is bad enough in adults, but still worse in children, whose bones have not acquired their full degree of firmness, and which, if compressed at this period, are forced permanently into a position which greatly diminishes the capacity of the chest.

The importance of fresh and pure air, in respect to respiration, will also force itself on the attention of every reader of the foregoing remarks. We see its invigorating qualities amply displayed in the superior bloom and vigour of the inhabitants of rural districts, as compared with town bred artizans, even though the latter should be equally well fed and clothed; and we can readily understand, when we consider the deterioration produced on the atmosphere by the smoke and other impurities arising from large towns, the important effect which change of air, as it is called, that is, the removal from an impure to a pure atmosphere, frequently has in establishing the convalescence of town patients. The same remarks with regard to the necessity for good fresh air, apply with still greater force to the apartments in which we dwell. One would naturally suppose that little argument would be required to enforce the necessity for a free ventilation, especially in sleeping apartments, and more particularly still in rooms where there are invalids; but we have in our own experience known no little authority required to be exercised in obtaining, especially among the poorer classes, a free admission of air into their chambers. The fear of the patient "catching cold" is the great bugbear. But people never seem to reflect how little they give fair play to the efforts of nature, or the powers of remedies in alleviating diseases, when they leave an invalid to contend, not only with his own malady, but with circumstances which impede the due performance of one of the most important of his bodily functions. Moreover, when we bear in mind the important fact, that by the very act of breathing we not only consume the oxygen of the atmosphere, but replace it by Carbonic Acid, a gas which is positively noxious, we will see with double force the im-

portance of renewing the air of our apartments; and we will easily perceive that crowded rooms, where the air is more than usually vitiated by the conjoined respiration of many individuals, are especially unfitted for delicate subjects who require a conjunction of all the circumstances most favourable for preserving their functions in a healthy state.

This constant generation of Carbonic acid by the respiration of animals may suggest to many persons the idea that the atmosphere of our globe must be constantly undergoing a deterioration in its qualities, especially when they are further informed that the same noxious gas is generated in immense quantities by many other processes constantly going on, such as combustion and fermentation. But this is not the case; and we take this opportunity of citing a beautiful illustration of the fact, that in the splendid designs of the Creator, there is no such thing as an arrangement which must ultimately lead to the defeat of the purposes for which it was designed. Animal respiration, if not counterbalanced in some other quarter, would, in process of time, inevitably destroy the whole population of the earth. But we find the compensating power in the analogous process of respiration in vegetables; whilst animals consume the oxygen and evolve Carbonic acid, plants, on the contrary, decompose Carbonic acid, appropriate to themselves the Carbon it contains, and set free its oxygen. Thus we see how the various parts of the great system of the universe harmonize together, when we find the two great kingdoms of animated nature supplying to each other a means of subsistence, which neither could for any length of time enjoy, if it existed alone and isolated.

Of Animal Heat.

One of the most marked phenomena observable in the bodies of living animals, is their tendency to maintain a certain temperature, which in all regions except under the torrid zone, is generally higher than that of the surround-

ing atmosphere. This power of evolving heat from their bodies enables animals to exist through the different vicissitudes of climate and season. Nature has provided the lower animals in the form of fur, feathers, and other appendages of the surface, with the means of preserving this temperature when the surrounding air is much colder ; and, as we shall presently shew, the clothing of man is regulated in cold seasons with a view to prevent the natural heat of the body from passing away from it. There cannot be the least doubt that the temperature of the external parts and extremities of the body depends upon the maintenance of the circulation through them. If we obstruct the flow of blood through the principal artery of a limb, an operation which is frequently performed by surgeons for certain diseases of the blood-vessels ; the first effect which follows is a lowering of the temperature of the limb operated on. At the same time there are many circumstances which shew that the origin of the heat of the blood is to be traced to the action of respiration. Thus in hybernating animals, i. e. animals which remain during winter in a torpid state, where the respiration is always very feeble, it is observed that when they are roused, in proportion as the breathing becomes more frequent and fuller, the heat of their bodies is augmented ; and in animals which have been decapitated, it has been found that if the action of breathing is maintained artificially, the cooling of the body is very much retarded ; whereas if the respiration had not some effect in maintaining the heat of the body, the cold air thus introduced into the chest must have accelerated instead of retarded the process of cooling. Moreover, analogy has long led chemists to infer that the formation of carbonic acid in breathing must have some connexion with animal heat, for it is well known that wherever carbon and oxygen combine to form carbonic acid, as in ordinary combustion, heat is evolved. But it is obvious that if the production of animal heat were due solely to what might be called the combustion of carbon in the lungs, we should

have the heat of that part of the body very high, and the rest of the body comparatively much colder. Now this is found not to be the case, and hence we infer that we must look to some other point for the production of animal heat. We have already shewn that it seems most probable that the carbonic acid given off in breathing is formed, not in the lungs, but in the course of the circulation, and therefore if the combining of carbon with oxygen be the source of the heat, there is reason to suppose that its evolution takes place, not in the lungs, but in the capillaries over the whole body. Further, it appears from many experiments that arterial blood has what is called a greater specific heat, that is, has the power of retaining more heat than venous blood. Consequently, when the blood in the capillaries passes from the arterial to the venous state, being now unable to retain so much heat, part of this must be evolved; and therefore, it is now most commonly believed, that the evolution of heat in Animal bodies, takes place not in the lungs but in the capillaries. The original production of the heat, however, is still most probably in the combination of carbon and oxygen in the lungs; but as the heat thus generated is immediately absorbed by the arterial blood, and carried by it to be evolved in the capillaries, it does not appear in the lungs in excessive quantity, as we would otherwise expect it to do. It has been inferred from other experiments and observations, that injuries of the nervous system have an important influence over the animal heat, and hence it has been supposed that the production of the high temperature of animal bodies is connected with the action of the nerves. But it seems more probable that the effects of these injuries are due to the power which the nervous system is well known to possess in modifying the circulation in the capillaries. We might easily enlarge much further upon this curious subject of speculative inquiry, but we prefer to make it practical by offering a few observations on the means which we adopt to preserve the temperature of our bodies. But

in order to render these intelligible, we must premise a few brief observations on heat generally.

Heat, or as it is usually termed by chemists *Caloric*, is a material substance, but not possessed of any appreciable weight, which pervades all bodies in greater or less quantity. Its most remarkable property is, its tendency to diffuse itself throughout space, or through every body with which it comes in contact. When any body is heated, that is, when a large quantity of caloric has been introduced into it, the caloric has a tendency to pass off into any other body that is near it, and this diffusion of the heat goes on until both the bodies come to the same temperature. There are two ways in which caloric may pass from any heated matter. It may fly off, as light does, in rays passing through the air until it meets with some substance which absorbs it; or it may pass away from the heated body, along any substance placed directly in contact with it. The first of these ways is called *Radiation*, the second is *Conduction* of Caloric. Thus, when we light a fire in a room, the apartment becomes warm, because rays of heat pass into it by Radiation; and if we put the point of a poker into the fire and keep it there, by and by the handle of the poker becomes hot, because heat has passed along the piece of metal by conduction. But heat is not conducted along all substances with equal rapidity. Some substances transmit it very rapidly, others very slowly, and in proportion as they do so, they are termed good or bad conductors of Caloric. Thus, it is quite obvious, that if a heated body is surrounded by a bad conductor of heat, it will part with its caloric (that is, it will cool) much slower than it would do if surrounded by a good conductor. Now it is precisely on this principle that we proceed in the selection of materials for forming our clothing. The heat of the human body is about 98 degrees of Fahrenheit, but as the temperature of the air in temperate, and still more in cold climates, is much lower than this, it is evident, that in accordance with the law of diffusion of caloric, the heat of our

bodies must have a constant tendency to pass off into the surrounding atmosphere. In order, therefore, to prevent the cooling of the surface which would thus ensue, we surround our bodies with substances which are bad conductors, and which, therefore, prevent our animal heat from passing away from us.

The materials of which clothing is made are chiefly Wool, Silk, Hair, and Down, from the animal kingdom, and Cotton and Linen from the vegetable kingdom. Of these, wool, from its being a very imperfect conductor of heat, and being at the same time, an abundant commodity, is most employed to retain the natural heat of our bodies, that is to form warm clothing. Raw silk, raw cotton, and hair, are as bad conductors as wool, and would, therefore, be equally warm; but silk and cotton are only used as clothing when woven, and then they do not retain the heat so readily, for we may remark, that the manner of manufacture has an important effect in modifying the conducting power of the substances. Generally speaking, the looser the texture, the better will it maintain the temperature of the body; because it acts not only in virtue of its non-conducting power, but being in this loose state, it retains amongst its particles a quantity of warm air in contact with the surface of our bodies. These facts are well illustrated by what we observe in the lower animals. The woolly fleece of some quadrupeds; the abundant hair of others; the feathers and down of birds, and the thick layer of fat or blubber under the skin of the whale, are all non-conducting substances, which have been placed there by the beneficent hand of the Creator, to maintain and preserve their animal heat within their bodies. Man again, who has the privilege of reason, is not furnished by nature with these protections in his own person, but is left to the guidance of his intellect, to select from the sources around him the materials which will best serve to retain his animal heat, in whatever proportion the temperature of the climate in which he is placed may render necessary.

We think, that from what has been stated, that the importance of warm clothing placed next the body so as to suffer none of the heat to escape, will be obvious to all, especially when we consider that our climate is very variable, and often extremely cold.

But this conviction will, we think, be strengthened, when we consider the effects of cold on the body. Whenever a portion of the body parts with its caloric, when, in short, it has become cooled in any way, the blood-vessels of the part become constricted, and of course, the blood is prevented from circulating freely through them. Now a very large proportion of blood in the natural state of the body circulates through the skin, and it is clear, that if the vessels of this part become constricted, the blood must pass into them in smaller quantity, and will, therefore, be obliged to find its way in undue proportions into other parts. Hence, when the surface becomes chilled, we have morbid effects produced in internal organs, just because the blood is, as it were, forced into them in improper quantity, from its not being allowed to circulate freely in the superficial parts of the body. Hence arise inflammations, catarrhs, sore throats, and bowel complaints, which, especially in the changeable weather of spring and autumn, so frequently require the aid of the Physician. The proper preventive for all this, is covering the body with a good non-conductor, which will retain the animal heat and prevent it from passing off into the surrounding atmosphere. We repeat, that we know nothing so valuable in this climate for preserving health as warm woollen under-clothing. We have seen many constitutions broken up by the want of this simple protective, but we never saw any injured, or, as is often foolishly supposed, rendered less hardy by using it.

We have thus considered the sources from which the blood is derived, the manner in which it is circulated, the process by which it is purified, and the way in which it maintains the heat of the body. We have now briefly to notice the fact, that certain substances are thrown off from the body which are either unessential or injurious to it.

Of Absorption and Secretion.

A constant series of changes go on in the bodies of animals by the removal of particles of the tissues, and the deposition of fresh matter in their room. These processes constitute respectively *Absorption* and *Nutrition.* They go on insensibly, and, at least in adult animals, are in the state of health so nicely balanced, that no alteration in form or structure is perceptible.

That a constant renewal of the particles does occur, is proved by many considerations. If portions of the body were not being daily carried off, it is obvious that every supply of nutriment taken, after the body has attained to the adult state, would add to its bulk, and the increase in size would be continual. Further, we observe that when nutriment is not supplied, as during starvation or diseases which interfere with the function of digestion, the body soon becomes emaciated, an effect which can be due only to the removal of portions of its textures. The agents which are concerned in the performance of this act of absorption are chiefly a set of vessels called Lymphatics. These are distributed through almost all the textures of the body. They resemble in structure, as they do in function, the Lacteals described in connexion with the digestive organs, and like these, they all in some part of their course pass through certain glands, which are placed chiefly in small groups in different parts of the body, as in the groins, arm-pits, and the sides of the neck. Both the Lymphatics and Lacteals are included by anatomists under the denomination of the *Absorbent System,* and they have this in common, that both series of vessels, when traced from their extreme branches to their ultimate destination, are found to pour their contents into the large veins near the heart, and thus mingle the fluids they carry with the venous blood. We have already described the contents of the Lacteals, under the name of the chyle. The fluid contained in the other class of absorbents

is called *Lymph*. It is a pale yellow, or colourless, clear fluid, which, under the microscope, appears to contain transparent globules. It contains fibrine, and some albumen in solution, but no red particles, and it has the power of coagulating when withdrawn from the body. It thus appears to be strictly analogous to the fluid part of the blood, and, in fact, some modern physiologists regard the blood as being nothing else than lymph with red globules suspended in it. Now, as we see that this lymph is again mingled with the blood in the circulation, it is obvious that it must be of some use in the economy of the animal, and, in fact, it is very probable that the lymph is nothing else than a portion of the fluid part of the blood, returning towards the heart, after having deposited its red globules and other constituents in the tissues of the body.

Here, then, we see another wonderful process going on in our bodies, by which a substance which is unessential to the perfection of the tissues of the body is removed from them, but being still applicable to useful purposes in the economy, it is retained within the body, and is mingled again with the blood, from which it appears originally to have been derived. But there are some other matters which are not only unessential to the perfection of the tissues, but are noxious if retained within the body at all. These are thrown off from the body chiefly in the form of certain fluids which are called *Secretions*, or, to mark their being destined to be thrown out of the body, *Excretions*. The word Secretion is also used to express the function by which these fluids are eliminated. It is generally performed by certain bodies, often already alluded to, called *Glands*, and frequently, also, it takes place from membranes; but whatever form the secreting organ may assume, it consists essentially of a free surface, on which a fine network of innumerable small capillaries can be observed. These vessels have no open mouths, but their coats are very thin, so that they probably permit fluids to transude through them. The fluids secreted by different

organs vary remarkably in their nature and composition; and it is one of the mysteries of Nature which have not been penetrated, that the particular substances which pass off with the secretions should be formed in certain organs only, and not by all indifferently. We shall briefly mention one or two of the secretions by which useless matters are separated from the body, not with the view of describing them individually, but merely as illustrations of the general remarks which we have made above. The examples which we select are the *Bile*, the *Sweat*, and the *Urine.*

The *Bile* is a yellow ropy fluid, which we have formerly noticed as playing a part in the process of Digestion. It undoubtedly serves a useful purpose there, but its most important constituent, a yellow resinous bitter matter, appears to be wholly useless, and is destined merely to be thrown out of the system. It is never found in any of the fluids or tissues of the body except in cases of disease, when it appears in all parts of the system, constituting the state of jaundice; it is found in large quantity in the excrementitious matters of the lower bowels, and is discharged along with them. Further, the severe symptoms which occasionally attend the complete suppression of the biliary secretion, show that it is not only useless, but hurtful, if retained in the system.

The *Sweat*, or *Perspiration*, is secreted by the skin; and the object of this function seems to be chiefly to throw off superfluous watery particles from the system. The perspiration is constantly passing off from our bodies in the form of a fine invisible vapour, but when it is augmented in quantity, it collects in fluid drops on the surface. These two forms of perspiration do not differ essentially in quality, but they have received respectively the distinctive appellations of the *Insensible* and *Sensible Perspiration.* One of the most important purposes of this secretion appears to be that of keeping the body cool by the constant evaporation from the surface. It is only on

this supposition, that we can explain the remarkable fact, that human beings can exist in dry air heated considerably beyond the boiling point of water, without having the temperature of their own bodies raised more than four or five degrees of the thermometer.

The *Urine* is one of those secretions which is more peculiarly designed to remove a noxious matter from the system. It is secreted by two well known organs, the kidneys; and besides a large quantity of saline matters dissolved in water, it contains, as its characteristic ingredient, a chrystallizable substance called *Urea.* That this is injurious if retained in the system, is proved by the fact, that in animals whose kidneys have been extirpated, or in cases of disease, where the secreting function of these organs is arrested, death very soon ensues, preceded by a remarkable state of insensibility closely resembling poisoning by opium or other narcotic substances; and when the bodies of those who thus perish are examined, the urea is found to have been carried with the blood throughout all the system, and can be detected by chemical means in the brain and other organs. But, besides separating urea, the urine is also a channel for getting rid of the watery parts of the fluids. In this respect it is vicarious with the perspiration, that is, when one of these secretions is diminished, the other serves instead of it. Thus, in warm weather, where most of the moisture passes off by evaporation from the surface, the urine is smaller in quantity, but is, if we may use the phrase, stronger, *i. e.* the solid matters dissolved in it pass off in equal quantity, but the proportion of water in it is diminished; whereas, in cold weather, where excessive evaporation from the surface would be injurious, the urine is in larger quantity, but less concentrated, its watery part being very much increased.

There are many other secretions which would furnish interesting matter for further discussion, but we avoid them, because we think we have stated enough to illustrate the fact, that there are channels provided by which what-

ever is useless or detrimental is removed from the system.

We have thus brought to a conclusion our sketch of some of the more important points connected with the Physiology of Health. We could have wished to have conjoined with it some more observations of a practical nature, but the size of our little volume has prevented this.

We will only, in conclusion, offer a single remark, as to the evidence furnished by the foregoing pages of the goodness and power of our all-wise Creator. This is no new subject, but it cannot be too often adverted to. It is pleasing to consider that we bear about in our bodies a testimony so unequivocal. If we contemplate the mechanism of a single organ,—the human heart,—inspect the construction of its beautifully-formed valves, and consider how delicate they are, and yet with what unremitting precision they can carry on the circulation of the blood during a long series of years, we shall have abundant reason to adore the wisdom of Him, by whom we have been "so fearfully and wonderfully made."

C. Whittingham, Tooks Court, Chancery Lane.